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Thesis

THE MORPHOLOGY OF THE AUTONOMIC NERVOUS SYSTEM IN ELASMOBRANCHS WITH PARTICULAR REFERENCE TO THE CHROMAPHIL SYSTEM

Submitted by

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OUTLINE OF THESIS

The Morphology of the Autonomic Nervous System in Elasmobranchs with Particular Reference to its Relation to the Chromaphil System.

In some fields of scientific work the knowledge that has been gained by the various investigators of a particular branch of work has been organized into a whole so that all who wish to study or read it, may do so. The morphology of the autonomic nervous system in Elasmobranchs and its relation to the chromaphil system has been studied from time to time by several scientists. The material, however, has never been assembled in one paper in concise form. This paper, therefore, will be for the purpose of bringing together all known facts on the subject in a logical form and order.

Preparation of this paper required the study of work done by many scientists over a period of seventy-five years. The scientists who have worked on the autonomic nervous system in Elasmobranchs have carried their experiments to some degree of success. It is evident that much of the work done was accomplished without reference to, and study of, previous experiments of a similar type. The works of Balfour (1878)

and of Leydig (1856) are the two outstanding ones of the time. Other scientists have verified the work of Leydig and of Balfour and have added more facts. To obtain a complete account of the subject at hand it is necessary to consider first the evolutionary theory of the development of the autonomic nervous system in Elasmobranchs and vertebrates in general.

II

Animal life consists fundamentally in the adjustment of the organism to two sets of primary conditions: those pertaining to the internal environment and those pertaining to the external environment. In the protozoa and primitive metazoa, adjustment to both these sets of conditions is accomplished by a more or less undifferentiated organism. As animals became more complex and correlated responses became necessary, this necessity was met in the organism by the development of a nervous system. This nervous system first assumed control of those functions which are primarily concerned with the adjustment of the organism to its external environment. As the interaction between the organism and its external environment became more complex, nervous control of the internal functions also be-

came necessary; consequently these functions were to some extent linked with the nervous system. Specialization continued to advance and division of labor within the nervous system itself became necessary and consequently, in all the higher metazoa and particularly in the vertebrates, a division of the nervous system arose which has to a large extent assumed the direct control of those functions which are primarily concerned with the adjustment of the organism to its internal environment (Kuntz 1911). This division is known as the autonomic nervous system.

Modern studies have shown that in all vertebrates the nervous system is derived exclusively from the ectoderm. In early stages of the vertebrate embryo the central nervous system develops very rapidly and in a short time becomes definitely outlined. The area which gives rise to the greater part of the nervous system becomes differentiated on the dorsal surface of the embryo. All further development of the nervous system advances from the central nervous system to the periphery. Thus the autonomic system is an off-shoot from the cerebro-spinal nervous system.

In the lower vertebrates the autonomic nervous system is so primitive that many investigators have

failed to recognize it as such. According to Johannes Muller (K '11) the functions of the autonomic nervous system in these animals are assumed by the vagi. It is reasonable to assume, in view of the facts available, that ancestral vertebrates possessed no nervous structure morphologically equivalent to any part of the system in higher vertebrates. In view of the fact that in all higher vertebrates the autonomic nervous system rises in ontogeny as an offshoot from the cerebro-spinal nervous system, it is highly probable that this division of the vertebrate system had its origin within the vertebrate series and that it arose comparatively early in the course of evolution. The autonomic nervous system found in some invertebrates bears no phylogenetic relationship to the autonomic nervous system of vertebrates. The course of evolution in the vertebrate and invertebrate groups has apparently been distinct as far as the nervous system is concerned although they have developed along more or less parallel lines. (Cambridge Library 1922)

The real point of origin of the autonomic nervous system cannot be definitely determined. The most primitive system which has been described in the vertebrate series is found in the cyclostomes. The part which is most highly developed in these

animals is closely associated with the vagi and is primarily concerned with the innervation of the blood vessels supplying the branchial apparatus (Kuntz 1911). Some scattered autonomic elements occur in the trunk region.

In all the lower vertebrates the vagi are comparatively large (Kuntz 1911), while the autonomic trunks are but poorly developed. With the development of the trunks the vagi become smaller and smaller. This decrease in the relative size of the vagi may be accounted for, in part, by the fact that the functions of the lateral line organs have been taken over by sense organs in the head region. Nevertheless, there is a reciprocal relationship between the degree of development of the vagi and of the autonomic trunks in the vertebrate series. (Bell 1830)

The digestive system probably came under nervous control comparatively early in the vertebrate series. Those parts of the autonomic nervous system which are most highly developed in the cyclostomes are closely associated with the vagi and are concerned primarily with the innervation of blood vessels supplying the branchial apparatus. The cardiac and autonomic plexuses in the walls of the visceral organs in the higher vertebrates are genetically re-

lated to the vagi. (Kuntz 1911). In the course of ontogeny these plexuses arise independently of, and simultaneously with, the autonomic trunks. These facts lead to the conclusion that the cardiac plexus and the autonomic plexuses in the walls of the visceral organs arose earliest in the course of evolution.

In the most primitive vertebrates the nervous control of the internal functions was, doubtless, assumed by the vagi. In these simple animals the internal functions were not to any great extent subject to nervous control. Even in highly specialized animals some of the internal organs, such as the pancreas and other glands, are now known to be stimulated by hormones produced within the body. (Harrow 1922). Muscular organs are also known to respond to myogenic stimulation. For example, the heart of a chick is known to beat normally for a considerable period before having nervous elements. In like manner it is probable that in the ancestral vertebrates the muscles in those regions of the digestive tube which were not innervated by the vagi carried on their normal function by stimulation which was direct until the necessity for this direct stimulation was removed by the development of an autonomic nervous system (Parker 1922).

With the advance of specialization the control of internal functions was shifted posteriorly. The main blood vessels in the trunk region gradually became innervated by neurones whose cell bodies remained with the cerebro-spinal nervous system or by cells which migrated peripherally along the spinal nerves (Kuntz 1911). As this migration continued many cells were attracted toward the aorta and the cardinal veins. The neurones, becoming aggregated along the aorta, afforded a second link in the viscero motor apparatus which gradually assumed a share in the nervous control of the visceral organs.

As the autonomic trunks became more highly developed their longitudinal fibers provided a pathway for the transmission of nervous impulses from one level of the trunk to another. These trunks may, therefore, be looked upon as the second step in the development of the autonomic nervous system. The development of the prevertebral autonomic plexuses probably represents the third stage in the evolution of the system.

The autonomic nervous system in the fishes and in the amphibians is essentially of the same type and is probably derived from such a simple type of autonomic nervous system as exists in the petromyzonts (Johnston 1906). As we ascend the scale of

animal development we find the system more highly developed.

III

The very early stages of development of the autonomic nervous system in Elasmobranchs is as yet unknown. All attempts to discover these early stages have been futile. The first branches of the system which can be found (Balfour 1878) are short branches from the spinal nerves which take a course toward the median line of the body, and terminate in small, irregular, cellular masses immediately dorsal to the cardinal vein. In the youngest of the Scyllium embryos, which were used for study, these have been detected but it has not been possible to determine definitely the anterior-posterior limits of the system, or to make certain whether the terminal masses of cells which form the ganglia are connected by a longitudinal commissure. In a stage slightly younger the ganglia are much more definite; the anterior one is situated in the cardiac region close to the end of the intestinal branch of the vagus, and the last of them near the posterior end of the abdominal cavity. The anterior ganglia are the largest. The commissural cord is

very indistinct. In a later stage the commissural cord becomes definite although not easily seen in longitudinal sections, and the ganglia become quite noticeable. Branches connecting them with the trunks of the spinal nerves may be seen without much difficulty. (Balfour 1878). In still later stages these branches cannot so easily be made out in sections, but the ganglia themselves continue as fairly conspicuous objects, occupying the intervals between the successive segments of the kidney.

The observations of Leydig (1856) and of Balfour (1878) seem to point to the autonomic nervous system as arising from the cerebro-spinal system in the form of an offshoot. Intestinal branches are developed on the main nerve stems of this system in the thoracic and abdominal region, each of these then develops a ganglion, and the ganglia become connected by a longitudinal commissure.

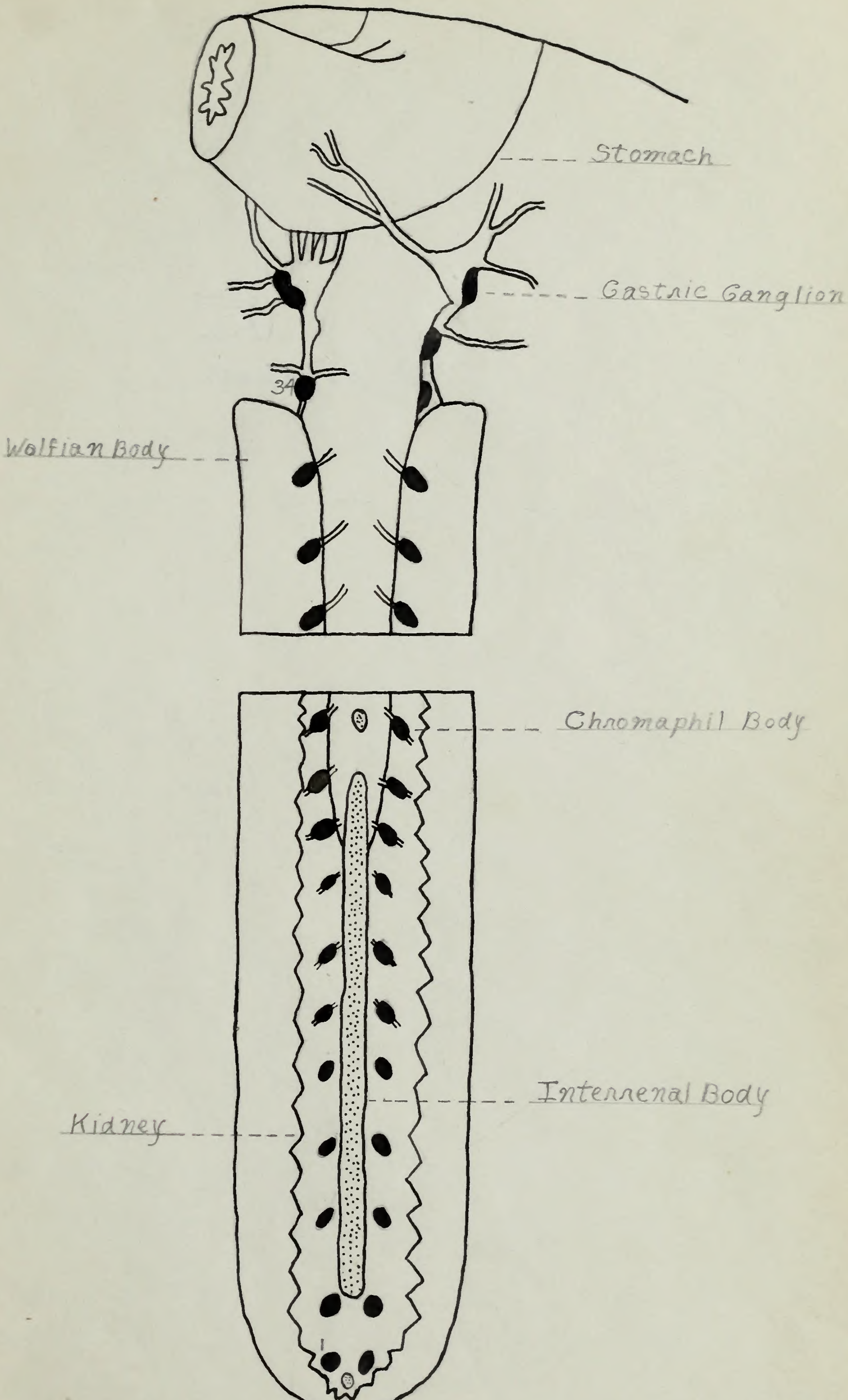
In Scyllium there are two structures which have gone under the name of the suprarenal bodies (Balfour 1878). One of these is an unpaired, rod-like body lying between the dorsal aorta and the caudal vein in the region of the posterior end of the kidneys. This body is the interrenal body. The other body is formed by a series of paired bodies situated dorsal to the cardinal veins on branches of

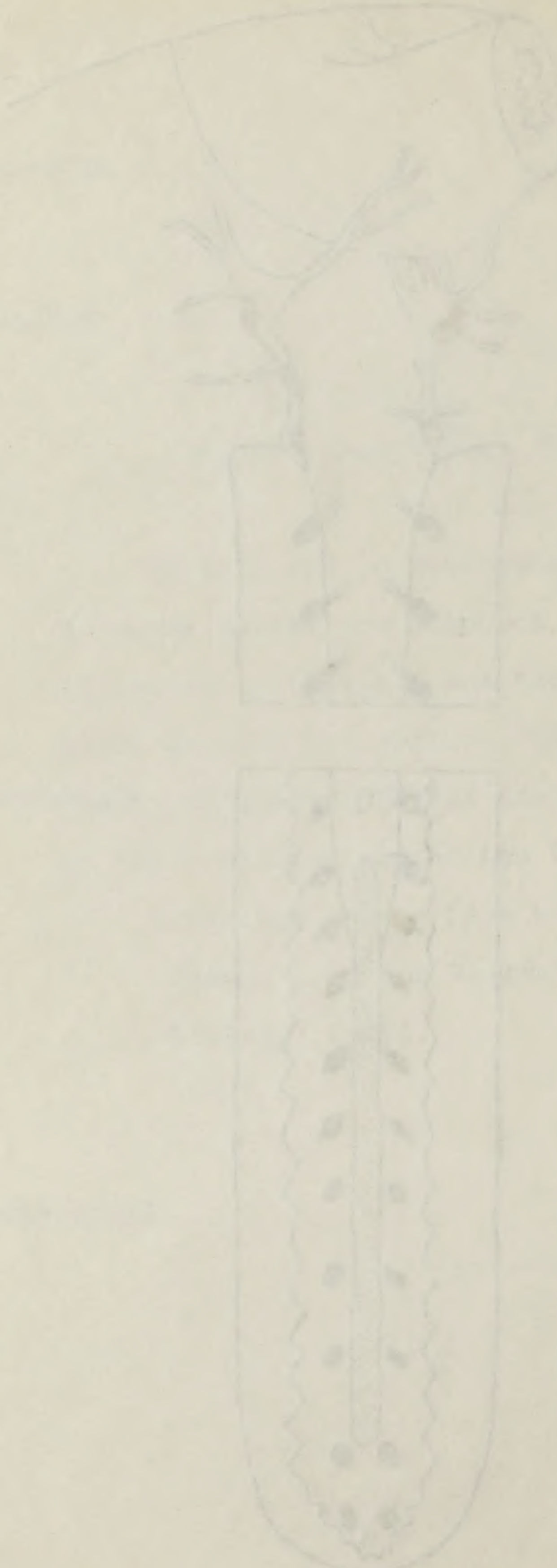
Drawing No. 1.

Squalus acanthias. Ventral aspect.

In this and in subsequent figures the interrenal bodies are stippled, the chromaphil tissue is solid black and the associated autonomic ganglia are white. The first and thirty-fourth chromaphil bodies are numbered beginning at the posterior end of the series.

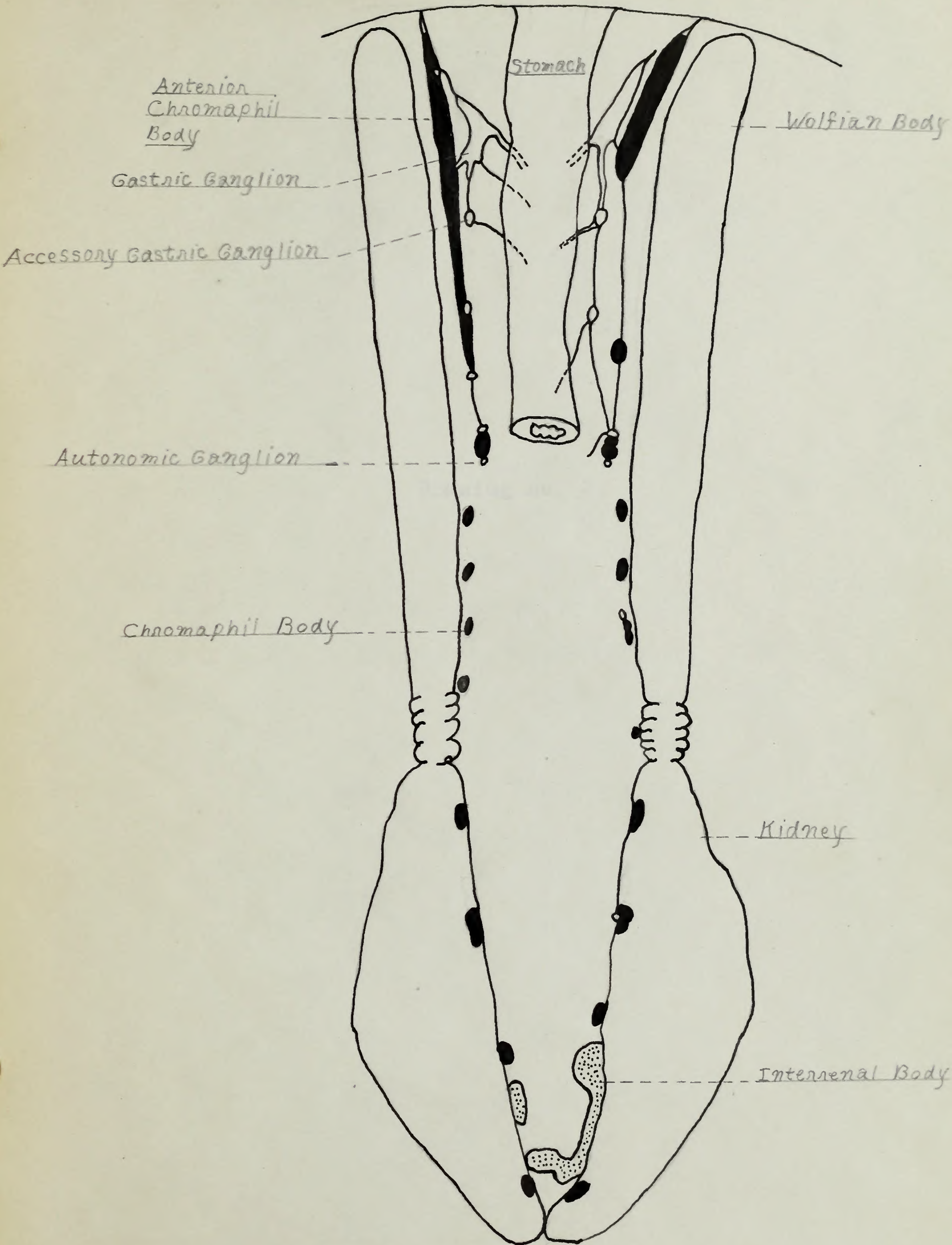
(Drawings one to five after Lutz and Wyman, from the Journal of Experimental Zoology, 1927).

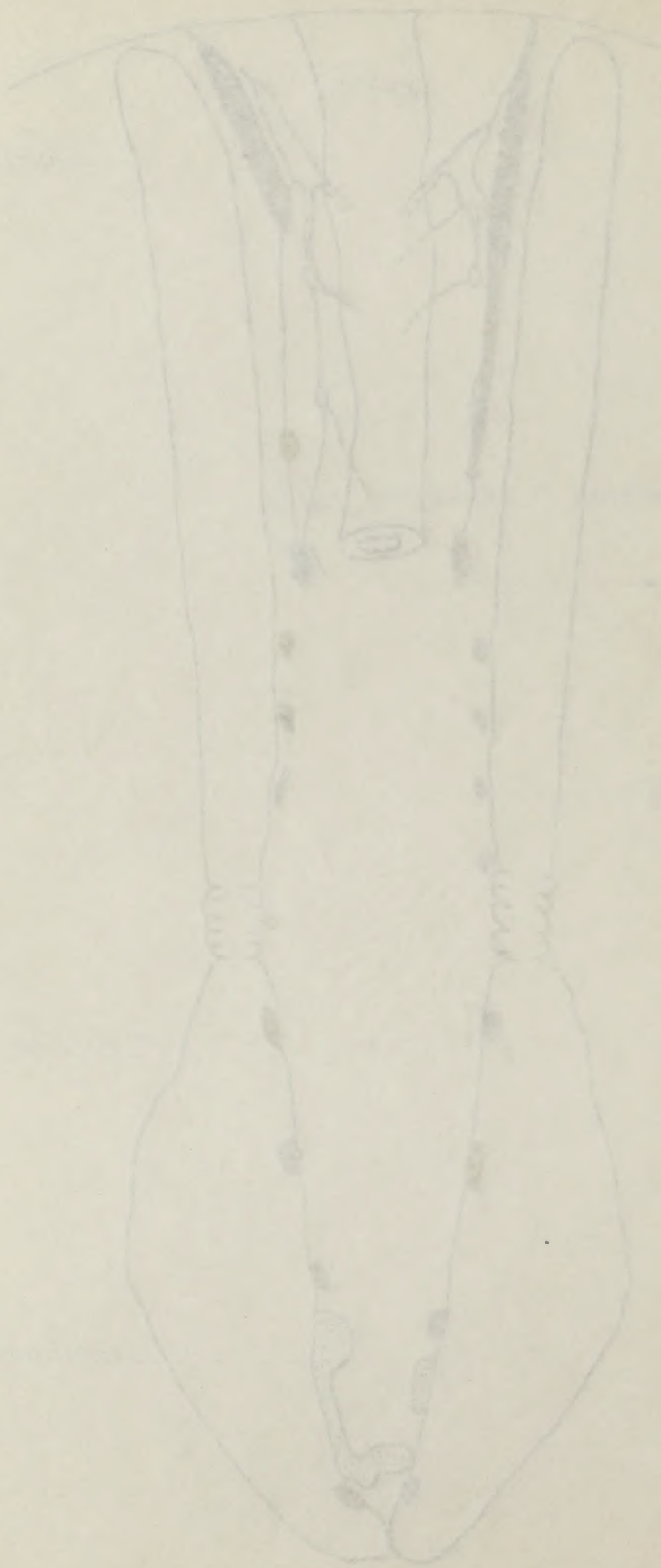

Stomach
Gastric Ganglion
34
Wolfian Body
Chromaphil Body
Interrenal Body
Kidney



Drawing No. 2.

Raia diaphanes. Ventral aspect.

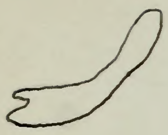

Stomach
Anterior Chromaphil Body
Gastric Ganglion
Accessory Gastric Ganglion
Wolfian Body
Autonomic Ganglion
Chromaphil Body
Kidney
Interrenal Body



Drawing No. 3.

Outlines of interrenal bodies of skates to show variation in size, shape and number.

A	Raia diaphanes	- male
B	Raia diaphanes	- male
C	Raia diaphanes	- female
D	Raia erinacea	- male
E	Raia erinacea	- female
F	Raia erinacea	- female
G	Raia stabuliforus	- male
H	Raia stabuliforus	- male
I	Raia stabuliforus	- male
J	Raia stabuliforus	- female
K	Raia stabuliforus	- female
L	Raia stabuliforus	- female



A

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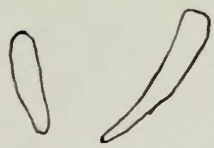

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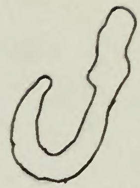

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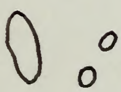

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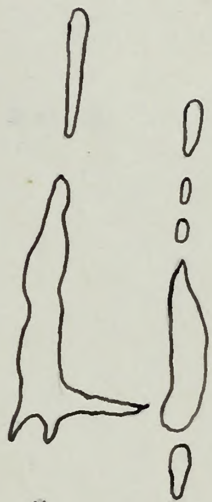

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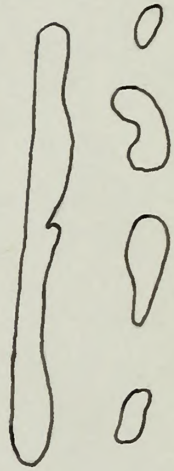

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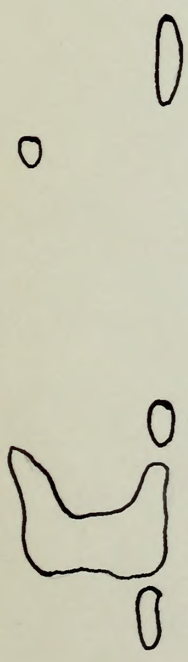
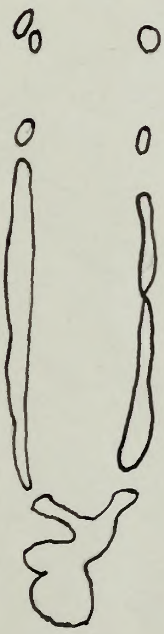
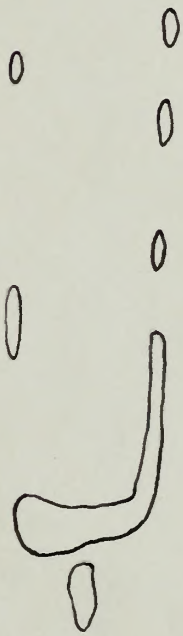


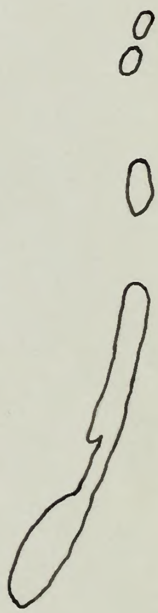
I



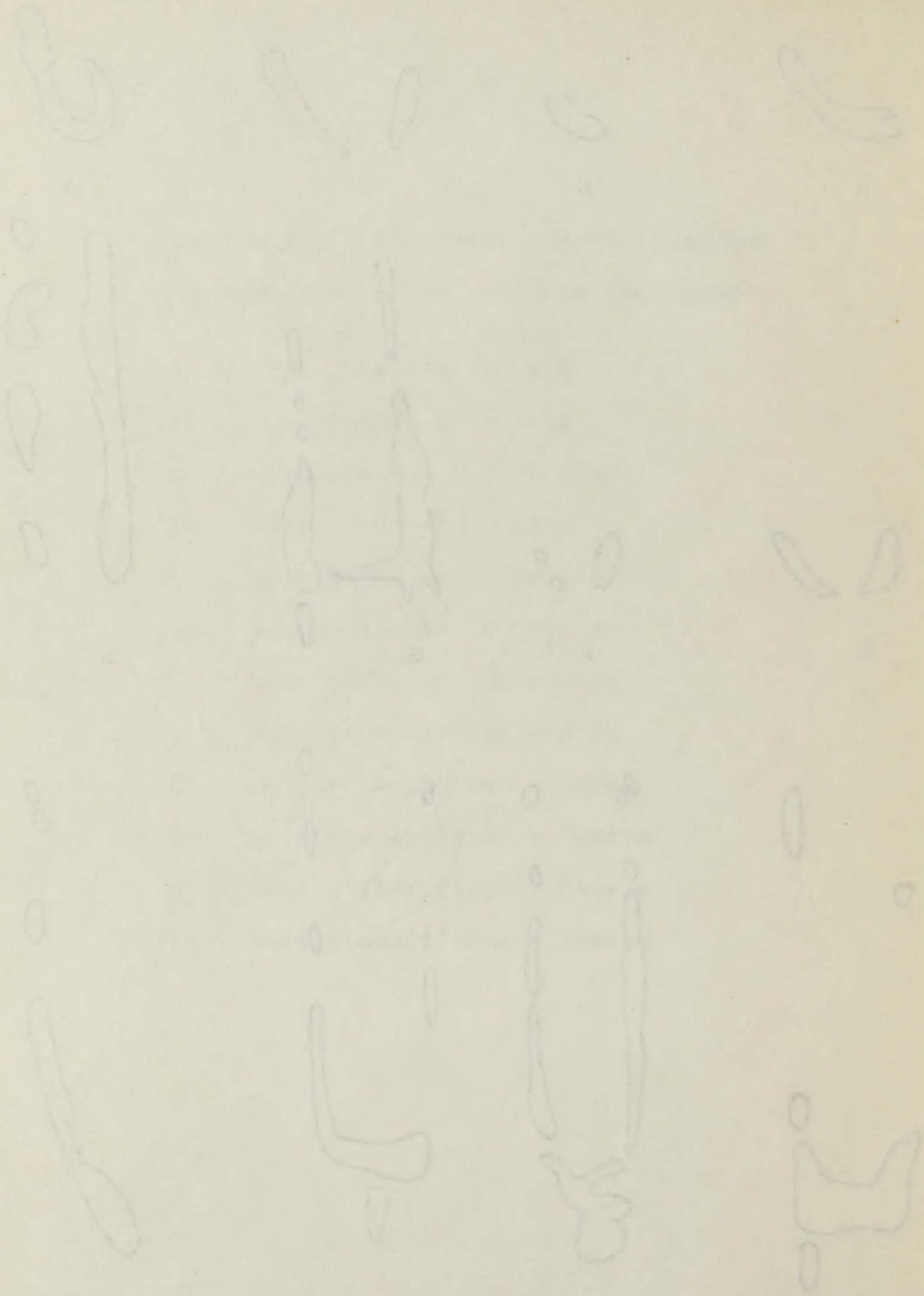
J



K

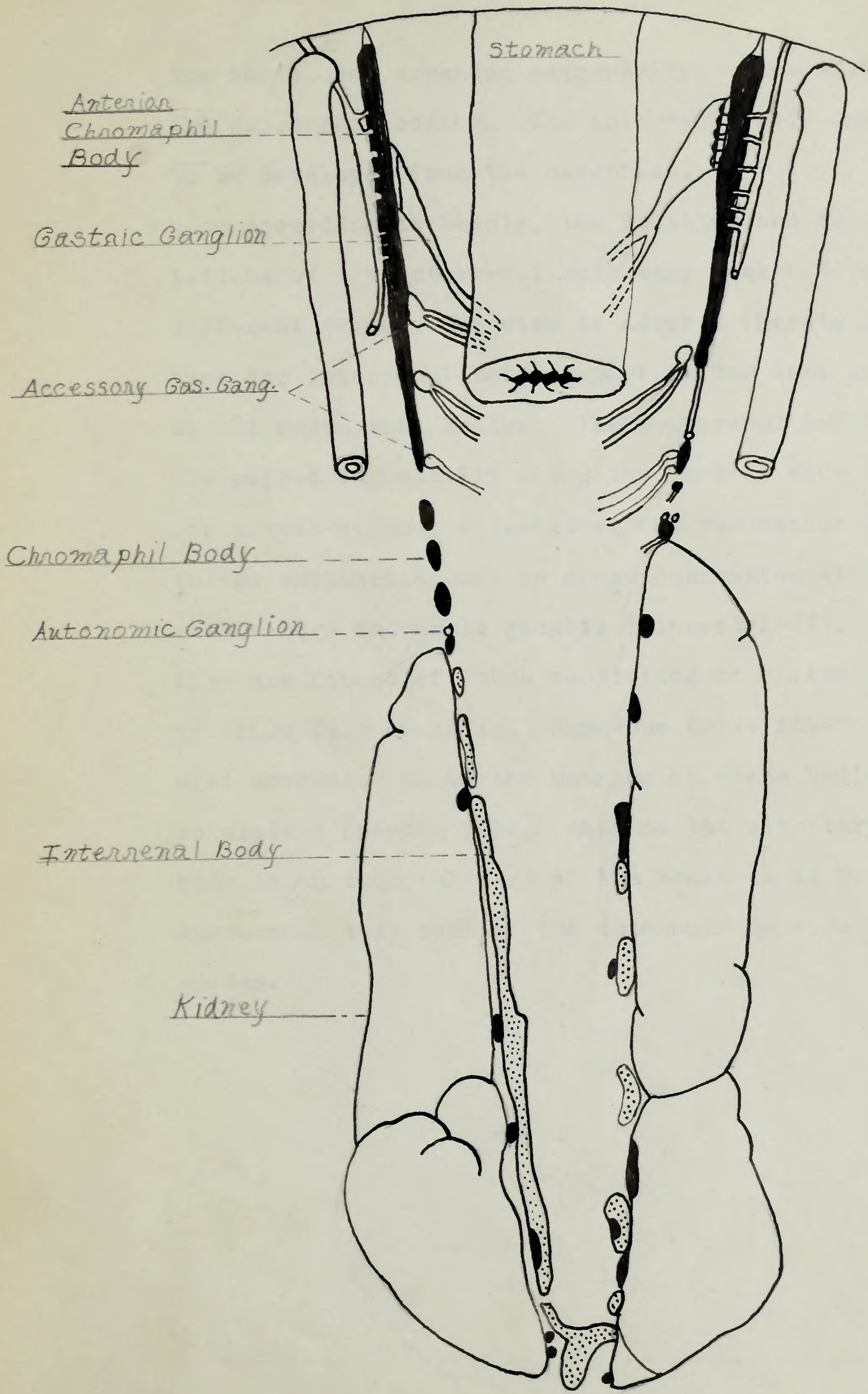


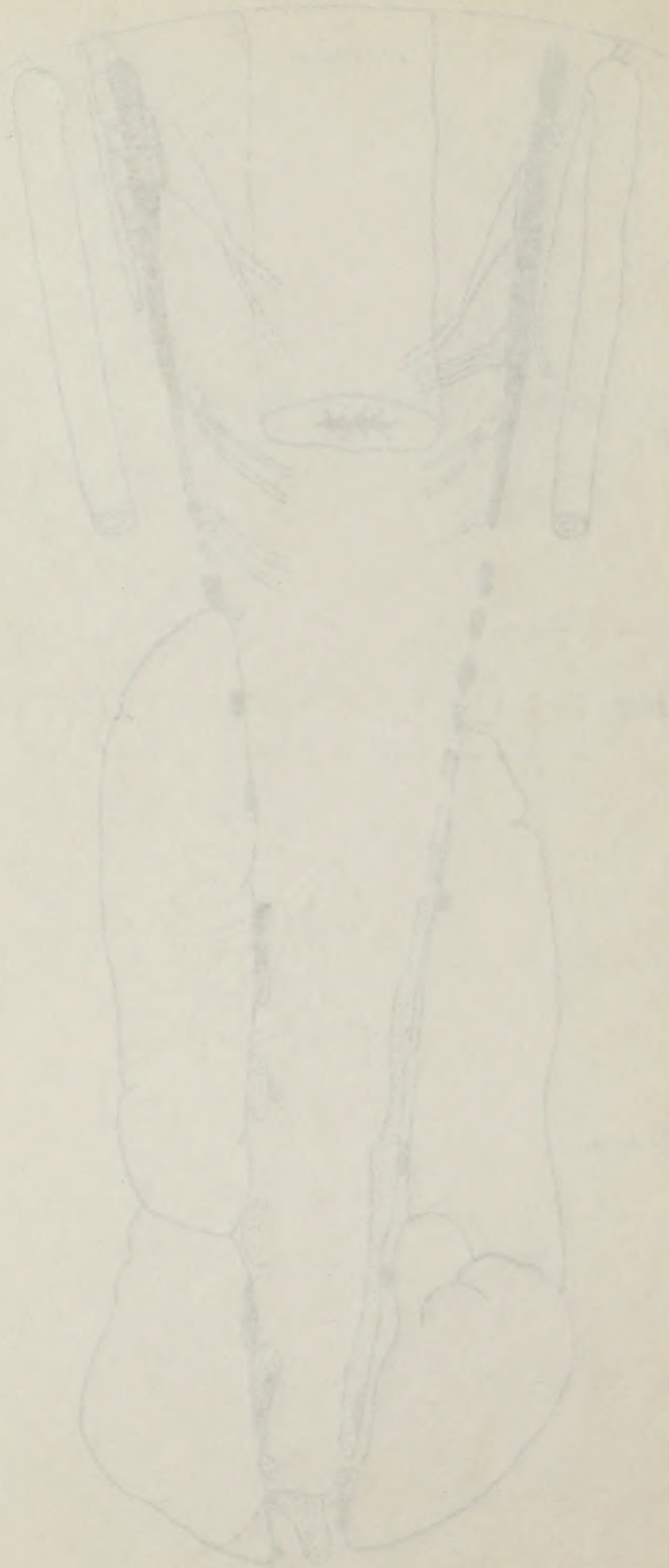
L



Drawing No. 4

Raia stabuliforus. Ventral aspect.


Stomach
Anterior Chromaphil Body
Gastric Ganglion
Accessory Gas. Gang.
Chromaphil Body
Autonomic Ganglion
Interrenal Body
Kidney



the aorta, and arranged segmentally. These are the suprarenal bodies. The interrenal body appears to be developed from the mesoblast.

According to Leydig, the position and relations of the interrenal body vary somewhat in different cases. The view is adopted (Leydig 1856) that the interrenal body is part of the same system as the suprarenal bodies. The suprarenal bodies are paired segmentally along the ventral side of the spinal column, situated on the successive arteries axillaries, and in close connection with one or more autonomic ganglia (Vincent 1924). They are formed of lobes consisting of closed vesicles full of cells. Numerous nerve fibers are also present. As to the meaning of these bodies it is claimed (Leydig 1856) that as the pituitary body is an integral part of the brain so is the suprarenal body part of the autonomic nervous system.

The terms, interrenal and suprarenal bodies, are sometimes used interchangeably by different writers. For the purpose of clearness in this paper, I will follow the terminology of Balfour. The interrenal body is that elongated one lying between the kidneys and often referred to as the "cortex". The suprarenal bodies are those bodies which are paired segmentally along the ventral side of the spinal column.

The anterior pair of suprarenal bodies in Elasmobranchs are the largest and are formed, apparently, from the fusion of two bodies. Under microscopic examination the connection of these bodies with the autonomic ganglia is obvious. Bound up in the same sheath as the anterior one is an especially large ganglion, and ganglia are more or less distinctly noticeable in all other suprarenal bodies (Vincent 1924). There is a considerable irregularity in the development and general arrangement of the sympathetic ganglia, which are broken up into a number of small ganglionic swellings, on some of which an occasional extra suprarenal body is found. As a rule there is much smaller ganglionic development

in connection with the posterior suprarenals than with the anterior suprarenals. (Vincent 1897).

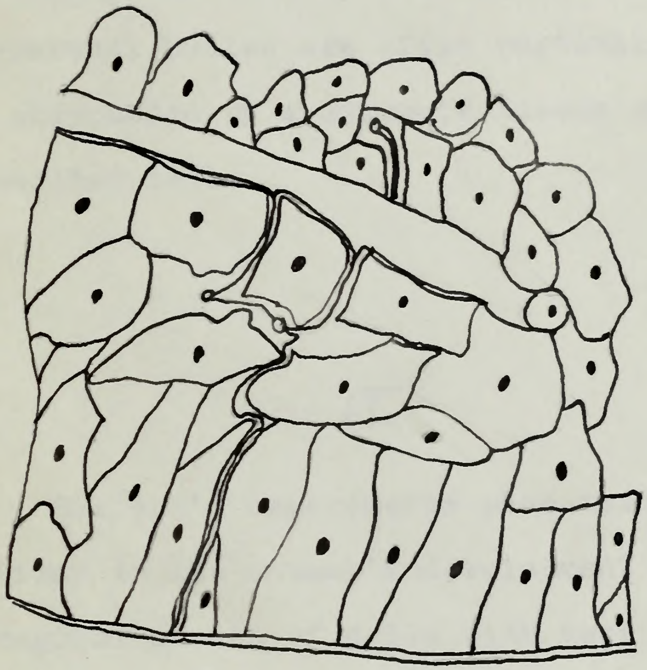
The different suprarenal bodies exhibit variations in structure mainly dependent upon the ganglion cells and nerves in them. Their typical structure is best exhibited in a posterior one in which there is a comparatively small development of nervous elements. In Scyllium there is present externally a fibrous capsule, which sends in the septa, imperfectly dividing up the body into a series of alveoli or lobes (Balfour 1878). Penetrating and following the septa there is a rich capillary network. The parenchyma of the body itself exhibits a well marked distinction in most cases into a cortical and medullary substance. The cortical substance is formed of rather irregular columnar cells, for the most part one row deep, arranged around the periphery of the body. Its cells measure about 0.03 m.m. in their longest diameter. (Balfour 1878).

The medullary substance is more or less distinctly divided into alveoli and is formed of irregular polygonal cells 0.021 m.m. in diameter. The character of the cortical and medullary cells is nearly the same, the cells differing more in shape than otherwise. The nuclei are small in comparison

Drawing No. 5

A section through part of one of the supra-renal bodies of an adult Scyllium. The section shows the columnar cells forming the cortex and the more polygonal cells of the medulla.

(Drawings five and six after Balfour)



to the size of the cell. In the anterior suprarenal body there is a less marked distinction between the cortical and medullary layers and a less pronounced yellow colorization of the whole than in the posterior bodies. The suprarenal bodies are often partially or completely surrounded by a lymphoid tissue which will be described later.

IV

Balfour's experiments show that approximately halfway in the animal's development they form irregular masses of cells with very conspicuous branches connecting them with the spinal nerves. There may be noticed at intervals, solid rods of cells passing through the body to the aorta. These rods are the rudiments of the aortic branches to which the suprarenal bodies are eventually attached.

In the following stage the trunks connecting these bodies with the spinal nerves are much smaller and less easy to see. Some nerves appear to attach themselves more definitely to a central and inner part of the ganglia than to the whole of

them. This is, no doubt, the first trace of a division of the primitive ganglia into a suprarenal part and a ganglionic part. The branches of the aorta have now a definite lumen and take a course through the center of these bodies as do the aortic branches in the adult.

In the next stage these bodies have acquired a distinct mesoblastic investment which penetrates into their interior, and divides it, especially in the case of anterior bodies, into a number of distinct alveoli. The nerve trunks uniting the bodies with the spinal nerves are very difficult to see. The aortic branches to the body are larger than in the previous stage, and the bodies themselves are more vascular.

Later development shows the presence of two distinct varieties of cells. One is large and angular and resembles the ganglion cells of the spinal nerves at the same period. This variety is in separate lobules or alveoli on the inner border of the bodies. These are most likely true ganglion cells though they are not connected with nerves. The cells of the second variety are also in special lobules and are smaller in size than the ganglion cells. They form the cells of the true suprarenal tissue. At this and at earlier

stages lymphoid tissue, like that surrounding the bodies in the adult, is found adjacent to these bodies.

Balfour and Vincent agree that we have the following grounds for regarding these bodies as suprarenal bodies and not as simple autonomic ganglia. First, a branch from the aorta penetrates these bodies and maintains exactly the same relations to them that the same branches of the aorta do in the adult to the true suprarenal bodies. Second, the bodies are highly vascular. Third, in the last stage they become divided into ganglionic and non-ganglionic parts, with the same relations as the ganglia and suprarenal tissue in the adult.

The evidence renders it almost certain that the suprarenal tissue is a product of the primitive ganglion and not introduced from the mesoblast without. (Balfour 1878).

The adult autonomic nervous system in Elasmobranchs, as is evident from the foregoing descriptions of development, is distinctly different from the autonomic nervous systems of higher animals. It is quite definitely linked up with the so-called medullary portion of the adrenal gland, represented in the Elasmobranch by the chromaphil

bodies which are the outer, darker portions of the suprarenal bodies (Vincent 1924).

V

In man the adrenal glands consist of two small bodies situated near the kidneys, each weighing about one-seventh of an ounce. They are often referred to as suprarenal bodies indicating that they are found above the kidney. They are also referred to as part of the chromaffin system, to indicate that their cells are colored brown with chromic acid (Harrow 1922).

The glands are in two very distinct parts. The medulla is a narrow body in which is found the hormone adrenalin. The outer part of the gland, or the "cortex", secretes a necessary substance which has so far been impossible to isolate. (Harrow 1922).

Complete removal of the gland in animals is followed by death within a few days, though the first two days do not necessarily show any signs of abnormality or disease. If an extract of the entire gland is administered it has no effect on the

maintenance of life (Biedl K '11). Neither does administration of the extract give favorable results in the treatment of Addison's disease which is caused by a decrease of the secretion in the gland.

Failure to cure Addison's disease is most likely due to the fact that the exact secretion of the cortex is not known. (Harrow 1922). The medulla secretes adrenalin which is a well known and important substance but evidence is accumulating to show that the medulla is no more important than the cortex and most likely is not the vital part. The cortex has been removed from animals (Biedl K'11) and the medulla left intact. This operation resulted in the death of the animal within a short time. Biedl, therefore, concludes that the cortex and not the medulla is most important to life.

What hormone, if any, the cortex contains is not clear. There has been no substance corresponding to the adrenalin of the medulla isolated from it (Harrow 1922). Various theories as to its function have been advanced. Among the most plausible theories are the following: First, the cortex is the real seat for the manufacture of adrenalin. Second, the function of the cortex is to destroy

poisons which are produced from the body or are introduced from outside the body. Third, the reproductive organs are influenced by the development of the cortex. The last theory is supported with fairly good evidence by Vincent, Balfour, and Harrow.

In the animal the adrenalin produced has a definite use; its effect being noticeable when the animal is under great emotional strain or rage. At such times the adrenalin entering the system causes constriction of the blood vessels, dilatation of the pupil of the eye, increased sweat, and a speeding of the heart (Martin 1925). These factors all make for the immediate protection of the body.

VI

The autonomic nervous system in man is divided into three parts or divisions. These are the cranial, the thoracico-lumbar, and the sacral divisions. The cranial division has the synapse in the organ affected. The head and trunk regions are affected by this division. Stimulation of any

cranial division constricts the pupil, increases the blood flow, increases the activity of salivary and gastric glands, increases the muscular activity of the alimentary tract, and slows the heart. All these effects tend to build up the animal and provide for remote protectiveness (Gaskell 1920).

On the other hand, collateral ganglia have to do with the immediate protection of the animal (Martin 1925). Stimulation causes constriction of the blood vessels, dilatation of the pupil of the eye, increase in sweat, and speeds the heart. The immediate protection of the animal is thus provided for.

The sacral division, like the cranial, has cell stations in the organs concerned. This division controls the activity of the caudal portion of the alimentary tract, the bladder and generative organs (Martin 1925).

A dual control of all organs and glands is maintained by the autonomic nervous system. An organ affected by the stimulation of the cranial division may be affected oppositely by the stimulation of the thoracico-lumbar division (Gaskell 1920). It is in the thoracico-lumbar division also that we get a condition similar to that caused by the flowing of adrenalin into the system. When the animal is enraged or emotion-

ally disturbed otherwise, and when the thoracico-lumbar division is stimulated, constriction of the blood vessels, dilatation of the pupil of the eye, and a speeding up of the heart takes place. This fact seems to prove Cannon's theory that adrenalin acts as an aid to the thoracico-lumbar division of the autonomic nervous system.

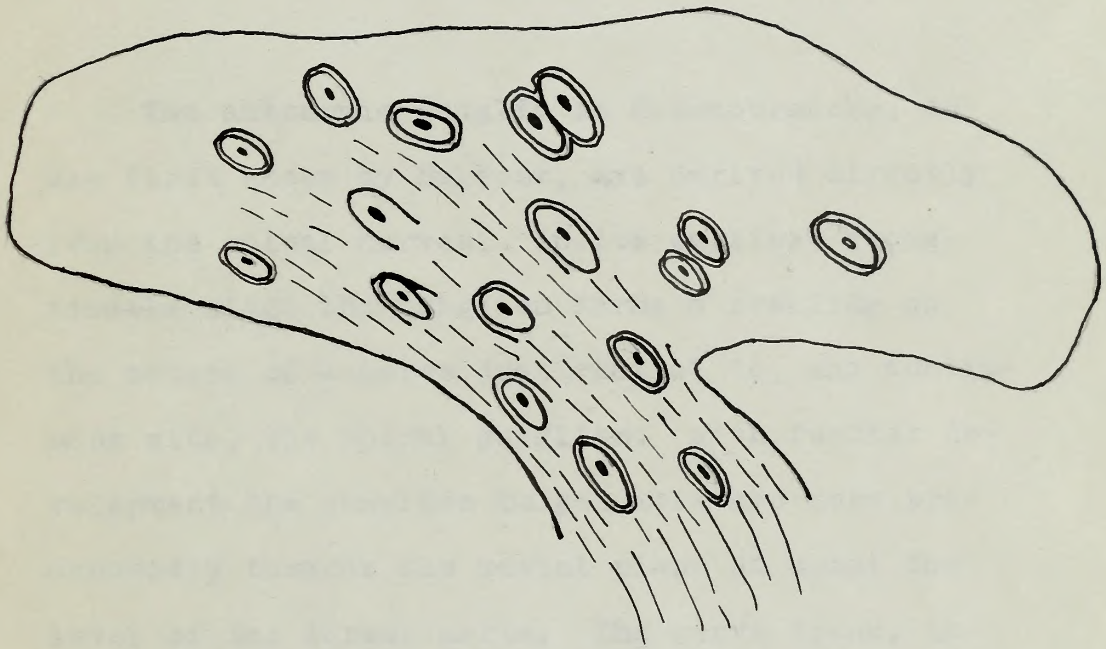
The adrenal bodies of mammals and of Elasmobranchs differ widely in form. The adrenal bodies of the former being compact masses each of which is composed of two parts, medulla and cortex. The medulla is surrounded by the cortex and is apparently in very close connection with it. In the Elasmobranchs the medulla is represented by the chromaphil bodies while the cortex is represented by the interrenal body. In the case of the mammal the relationship between the two parts of the adrenal body is close while in the case of the Elasmobranchs the relationship is remote. However, the work of the bodies in both species is thought to be the same; both producing adrenalin and acting as an aid to the autonomic nervous system. Both produce an unknown substance in the cortex also.

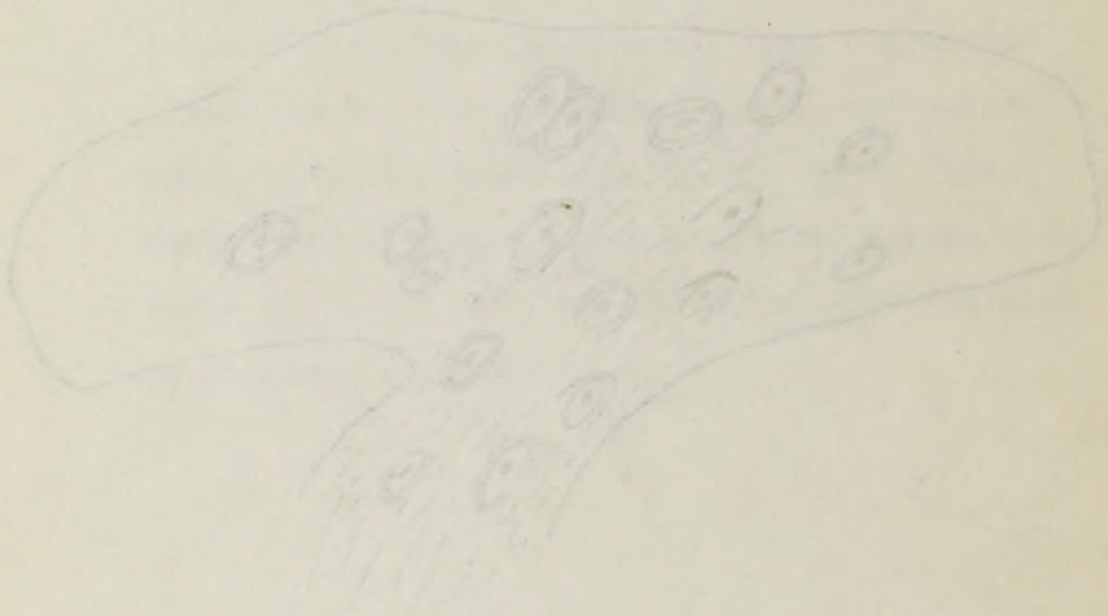
VII

In one of the posterior suprarenal bodies a small ganglion is generally found attached to both ends of the body and invested in the same sheath and in addition to this a certain number of ganglion cells are to be found scattered through the body. In the anterior bodies the development of ganglion cells is very much greater (Balfour 1878). Taking a section through a region where the large autonomic ganglion is attached to the body, one half of the section is composed mainly of sympathetic ganglion cells and nerve fibers and the other half of suprarenal tissue, with the former spread into the latter. The suprarenal tissue is not inserted but fills up the whole space within the outline of the body. At one point a nerve enters and in connection with this, a number of ganglion cells. They are scattered irregularly throughout the suprarenal body, but are more concentrated at the smaller end. It is this small end which, in succeeding sections, is entirely replaced by an autonomic ganglion. Wavy fibers are distributed through the suprarenal body in a manner which seems to be proportional to the num-

Drawing No. 6

Transverse section through the anterior suprarenal body of an adult Scyllium showing the autonomic ganglion cells which are scattered through the substance of the body. The entrance of the nerve and indications of the distribution of the nerve fibers are shown. The suprarenal tissue is not inserted but fills up the entire space between the outlines of the body. The small end has greater concentration of ganglion cells and it is this end which is later replaced by an autonomic ganglion.





ber of ganglion cells (Balfour 1878). At the large end of the body where there are few nerve cells, the typical suprarenal structure is maintained. In the small end the ganglion and nerves are so intimately united with the suprarenal body as not to be separable from it.

CONCLUSION

The autonomic ganglia in Elasmobranchs, as was first shown by Balfour, are derived directly from the spinal nerves. In its earliest recognizable stage the ganglion forms a swelling on the course of a nerve just ventral to, and continuous with, the spinal ganglion. With further development the ganglion bulges more and more pronouncedly towards the mesial plane at about the level of the dorsal aorta. The nerve trunk, in this region, now splits longitudinally and the ganglion becomes shifted farther toward the mesial plane, lying immediately over the posterior cardinal vein and remaining connected by a slender bridge, the ramus communicanus, with the spinal nerve from which it has become split off.

The problem of the mode of development of these obscure portions of the nervous system will

part of ganglion cells ([illegible] [illegible]). At the [illegible] [illegible] there are nerve cells, the [illegible] [illegible] [illegible] is [illegible]. In the [illegible] and the ganglion are so intimately united with the [illegible] as not to be separable from it.

[illegible]

The [illegible] ganglion in [illegible], as first shown by [illegible], [illegible] [illegible] from the spinal [illegible]. In the [illegible] [illegible] the ganglion [illegible] [illegible] of a nerve [illegible] [illegible] [illegible] ganglion. [illegible] the ganglion [illegible] [illegible] more and more [illegible] towards the [illegible] at about the level of the optic chiasma. The nerve [illegible] this region, the [illegible] ganglion becomes [illegible] [illegible] plane, lying immediately over the [illegible] and [illegible] Bulbus, the [illegible] [illegible] with the [illegible] from which it has become split off.

The position of the [illegible] [illegible] [illegible] positions of the [illegible] [illegible]

probably be only satisfactorily settled after we know with certainty the processes at work in the development of the main nerve trunks.

The suprarenal bodies in Elasmobranchs are paired segmentally along the ventral side of the spinal column, situated on the successive arteries axillaries, and in close connection with one or more of the autonomic ganglia. The connection between the autonomic ganglia and the suprarenal bodies is obvious, especially in the case of the first pair of suprarenal bodies, and more or less distinct in succeeding pairs. The structure of the suprarenal bodies exhibits variations which are mainly dependent upon the ganglion cells and nerves in them.

The outer, darker portions of the suprarenal bodies, represented in Elasmobranchs by the chromaphil bodies, correspond to the medullary portion of the adrenal glands of higher vertebrates. In man the adrenal glands consist of two small bodies situated near the kidneys. They are in two distinct parts; the medullary matter which forms the hormone adrenalin and the cortex which secretes an unknown hormone. The cortex in the human is represented in the Elasmobranchs by the interrenal body. This is a rod shaped body lying between the kidneys. The functions of the interrenal body and suprarenal

probably by many sources already obtained after we know much certainly the [illegible] of work in the development of the main nerve trunks.

The segmental bodies [illegible] paired, segmentally along the frontal side of the spinal column, situated on the ventral side between the main veins, and in close connection with the ventral of the autonomic ganglia. The connection between the autonomic ganglia and the [illegible] bodies is typical, especially, in the case of the [illegible] of the spinal cord, and [illegible] in close contact with the autonomic ganglia. [illegible] of the segmental bodies exhibits variations, which are mainly dependent upon the ganglion cells and nerves in them.

The other, another portion of the suprarenal system, represented in the [illegible] of the [illegible] bodies, corresponds to the medullary portion of the adrenal glands of higher vertebrates. It [illegible] the adrenal [illegible] of the [illegible] situated near the kidneys. They are in two distinct parts: the medullary matter, which forms the chromaffin [illegible] and the [illegible] tissue, an epithelial [illegible]. The cortex in the [illegible] is represented in the [illegible] by the interrenal body. There is a [illegible] [illegible] between [illegible] the [illegible] of the interrenal body and [illegible].

bodies in Elasmobranchs are comparable to the functions of the cortex and the medulla in man.

Collateral ganglia, when stimulated, provide for the immediate protection of the animal. The blood flow is increased, the pupil of the eye is dilated and there is an increase in sweat. Adrenalin from the medullary portion of the adrenal gland has exactly the same effect on the body as does the stimulation of the collateral ganglia. The adrenalin secreted by the chromaphil tissue in Elasmobranchs has the same effect as that secreted by the medulla in man.

It is evident that the relationship between the autonomic nervous system and the chromaphil system is one which is very close. The ganglion cells are well scattered through the suprarenal tissue forming an integral part of it. The concentration of the ganglion cells is greater in the small end of the suprarenal body and this concentration in the small end is later replaced by an autonomic ganglion. The action of the adrenalin given off by the chromaphil tissue acts as an aid to the nervous system in time of needed protection.

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Source of Drawings

Lutz, B. R. and Wyman, L. C.	Drawings one to five from the Journal of Experimental Zoology 1927
Balfour, F. M.	Drawings five and six from the Monograph on Elasmobranch Fishes Plate sixteen 1878